RESEARCH REVIEW
OFFICE of AEROSPACE RESEARCH

OAR:
The Basic Research Agency
of The United States Air Force

VOLUME II NUMBER 10 1 JULY 1963

Kerr Cell and Rotating Mirror Team Up to Take Fast Movies

PETER BLETZINGER, Plasma Physics Research Laboratory (ARH), ARL

High speed rotating mirror framing cameras rate among the most useful instruments to analyze rapid events like explosions, shockwaves and transient electrical discharges. Their advantages are high image quality, a long sequence of frames, and speeds up to eight million frames per second. Among the disadvantages are small optical opening, and as a consequence low illumination, and the fact that the event to be recorded must be triggered by a signal from the camera so that the event happens during the time when the mirror is in position to image the event onto the filmstrip. (These disadvantages have been overcome at least in part by special developments, i. e., cameras with openings up to F/4.0 and continuous access cameras).

Another difficulty with this type of camera is the need for a primary or gating shutter. Assuming a mirror speed of 10,000 rps (as available in commercial cameras), the time during which the sequence of frames must be exposed is approximately 12 microseconds if the film strip length corresponds to 90° of the reflected light beam revolution or to one eighth of a mirror revolution. The frames must be exposed only once, but the rotating mirror will continue to expose the film on subsequent revolutions unless a gating shutter interrupts the light path after the first exposure. The conventional solution to the problem is the blast shutter. A piece of plane parallel glass mounted in the light path is shattered by explosives blocking the light in a few microseconds. Other types of gating shutters have been introduced which use strong transient magnetic fields to either rapidly deform an aluminum foil so that it closes or opens the light path or to turn a thin membrane into or out of the light path.

The experiment for which we intend to use the framing camera calls for a shutter which opens and closes in the time interval of one revolution of the mirror; the target of the design is an "open" in-

terval not longer than the recording time in order to eliminate any reflections from the sides or back of the mirror. This precaution is essential because we intend to record a transient electrical discharge superimposed on a very bright continuous electrical arc. None of the available shutters mentioned before meets these requirements.

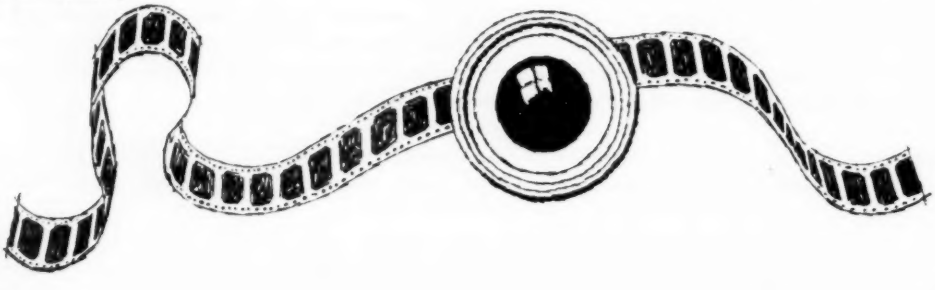
The high light levels of the pulse discharge to be recorded permit the use of a Kerr cell shutter even though the light transmission through an open Kerr cell is only 6 - 7%. A very large aperture Kerr cell was selected in order not to reduce the optical opening of the camera. Since the operating voltage of a Kerr cell is proportional to the electrode distance or the aperture, a special pulse generator using pressurized high voltage spark gaps had to be designed to operate this Kerr cell.

The open to close transmission ratio of such a Kerr cell is about 10^5 or, to illustrate by an example: If the open time is 10 microseconds, photographic film will receive the same amount of light in the closed position of the cell if the light source continues for one second. Hence, another mechanical shutter has to be added with an opening time of 10^{-3} second in order to preserve enough contrast between exposures through the open Kerr cell and light leakage through the closed Kerr cell. To achieve the required speed at the large aperture of the camera, an aperture slide is driven across a fixed aperture by strong leaf springs. The springs are so centered that the aperture slide reaches its maximal speed while crossing the fixed aperture and is caught in the end position by a catch lever when it is decelerated again by the overswinging springs.

To make an exposure the following sequence of events occurs: as soon as the mirror has reached the desired speed, the mechanical shutter is released by an electromagnetic actuator. Just before this shutter opens fully, an electrical contact activates the main trigger circuitry which generates a gate pulse denoting the time when the mechanical shutter is fully open. This pulse gates the inductive pick-up pulses from the mirror which signal that the mirror is in recording position. The first mirror pulse which passes the gate triggers the Kerr cell and also the event - the capacitor discharge in our case - at the proper instant.

To test the operation of the camera system, we have photographed a transient discharge superimposed on the d-c discharge of a high pressure mercury lamp. The growth of the discharge was recorded clearly and the timing was so precise that the start of the event could be synchronized with the first frame of the sequence.

The framing camera used was a Beckman-Whitley type 189 camera; the Kerr cell was obtained from Electro Optical Systems. The work reported here was performed by members of the Plasma Physics Research Laboratory.



world-wide *Riometer Network*

SAMUEL HOROWITZ, Upper Atmosphere Physics Laboratory, AFCRL

AFCRL has established a world-wide network of 19 riometer sites for monitoring cosmic noise and ionospheric absorption of galactic radiation. At each of these receiving sites there is an ultra-sensitive, transistorized riometer designed by AFCRL.

The riometer network will play a large role in monitoring solar disturbances during the International Year of the Quiet Sun (IQSY). A riometer--relative ionospheric opacity meter--measures the amount of radio energy from space penetrating the ionosphere. As the ionosphere increases in density, less radio energy from space can penetrate it. Ionospheric density is increased by solar disturbances, normal solar radiation, and nuclear explosions in or near the ionosphere.

Because of the last of these influences--that is, nuclear explosions--riometers are used to study the effect of these nuclear explosions on communications and on the diffusion of charged particles from atomic explosions in the ionosphere. Cosmic noise is absorbed to some extent by the Van Allen radiation belts as well as by the ionosphere. The level of radiation in the lower belt was greatly enhanced by the July 9 nuclear shot, and the decay rate of this enhancement is of great concern to scientists. Data from the AFCRL riometer net provide a rough indication of the rate at which this enhanced radiation will decay.

Most of the overseas riometer sites are operated without charge to the Air Force, although AFCRL supplied the basic equipment to foreign observatories. Local personnel, trained by AFCRL technicians, operate, maintain, and record the data which are forwarded to AFCRL for study. After installation, the only cost to the Air Force is for replacement parts. The following stations have been established to date: Thule, Greenland; Northern Maine; Bedford, Massachusetts; Copenhagen, Denmark; Garchy, France; Sacramento Peak, New Mexico; Rome, Italy; Athens, Greece; Haifa, Israel; New Delhi, India; Maui, Hawaii; Manila, Philippines; Trivandrum, India; Addis Ababa, Ethiopia; Huancayo, Peru; Natal, Brazil; Canton Island, Central Pacific Ocean; Accra, Ghana; Tierre del Fuego, Chile; Hermanus, R. of South Africa; Kerguelen Island, Indian Ocean; Christchurch, New Zealand; and Cape Hallet, Anarctica. AFCRL Project Scientist for the riometer network is Mr. Samuel Horowitz.

ULTRAHIGH PRESSURE RESEARCH IN THE SOLID STATE

MAX SWERDLOW, Solid State Sciences Division, AFOSR

For many years the Nobel Laureate, P. W. Bridgman, worked almost alone in the design of high-pressure apparatus (Figures 1 and 2) and investigation of the effects of high pressure on properties of materials. In 1955, however, the announcement of the synthesis of diamond, by the General Electric Company, aroused widespread interest in the potentialities of combined high pressure and temperature for the synthesis of new materials. Likewise, increased interest in the physics and chemistry of solids has spurred activity in the examination of pressure effects of electrical properties of semiconductors and on diffusion in metals and ionic compounds.

Under sponsorship of AFOSR, Dr. C. M. Schwartz and Mr. A. P. Young, of Battelle Memorial Institute, have been investigating the effects of pressure on the electrical properties of transition metal oxides and of combined pressure and temperature on compound formation in transition metal mixed oxide systems.

In high-mobility broad-band semiconductors such as germanium or silicon, the charge carriers, namely, electrons in the conduction band or holes in the valence band, are assumed to be nearly free. They interact with the crystal lattice only through thermal scattering or scattering by crystal defects. On the other hand, in low-mobility semiconductors, such as NiO, charge transport probably occurs in quite a different manner and is not yet well understood. In this case, charge transport may occur by a thermally activated motion of holes self-trapped at local sites by lattice polarization. If this mechanism is valid, pressure would be expected to decrease the carrier mobility in accord with observed pressure effects on other diffusion-controlled processes.

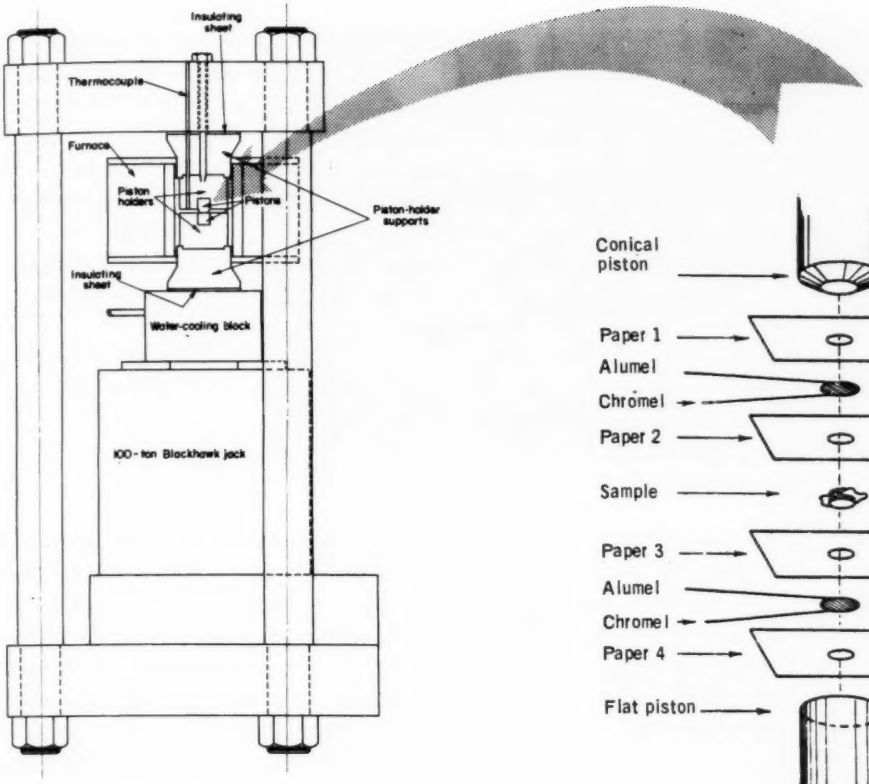


FIG. 1. Schematic of "Bridgman Anvil"

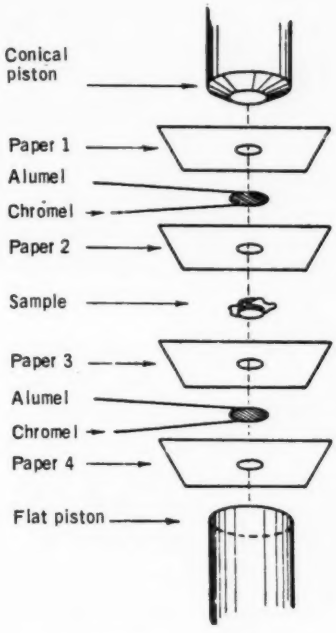


FIG. 2. Exploded diagram of high-pressure cell for measuring Seebeck coefficient of powder compacts.

In the present research, a decrease in carrier mobility with pressure was actually observed in the narrow-band semiconductors NiO, CoO, and CuO. However, a decrease in carrier mobility was also observed in Cu_2O, although Cu_2O is not generally regarded as a narrow-band semiconductor. For a better understanding of charge transport in these oxides, experiments will be conducted under hydrostatic pressure conditions and with single crystals where possible.

The development of crystal field theory has led to a better understanding of the role of ionic radius and electron configuration in the determination of crystal structure. It is often possible to predict possible crystal structures by analogy with the structure of known materials, based on the chemical relationships. Suppose,

however, that the radius of one ion is too small to form an analogous compound at normal pressure. Will the analogous compound be formed at high pressure? Some experiments designed to answer this question were conducted. $CrTaO_4$, $FeTaO_4$, $CrNbO_4$, and $FeNbO_4$ normally have the rutile-type crystal structure with six-fold coordination of oxygen ions around the cations. The radius of the vanadium ion is smaller than that of niobium or tantalum, and in the normally occurring crystal form of vanadium compounds of this kind, the vanadium coordination number is less than six. However, at temperatures of 1000°C and pressures from 60 to 90 kilobars, a rutile-type $CrVO_4$ was formed isomorphous with the normally occurring $CrTaO_4$ and $CrNbO_4$. The high-pressure $FeVO_4$ was not rutile-type, but had the wolframite structure in which the coordination around the cations is also six-fold.

$AlSbO_4$ is rutile-type with six-fold coordination around both Al and Sb. $AlAsO_4$ in the usual form has the quartz structure with four-fold coordination around both Al and As. The electronic configurations of As and Sb are $4s^24p^3$ and $5s^25p^3$, respectively, and the ions are therefore chemically similar, but the ionic radius of As is considerably less than that of Sb. However, at 90 kilobars and 900°C, a rutile-type $AlAsO_4$, isomorphous with $AlSbO_4$, was formed. It is evident from these examples that predictable structures may be formed at high pressure when ions are undersize.

Considerations of ion size and ion configuration have been quite successful in explaining and predicting crystal structures. However, there are some compounds which do not follow the rules. For instance, small cation tungstates $MgWO_4$, $ZnWO_4$, $MnWO_4$, $FeWO_4$, $CoWO_4$, and $NiWO_4$ form an isomorphous series having the wolframite structure. None of the corresponding molybdates have the wolframite structure at ambient pressure. This cannot be explained by present theory. At high pressure and temperature, however, all of the molybdates corresponding to the wolframite-type tungstates transform to the wolframite structure. The reason for polymorphism is not well understood; however, evidence that molybdates isostructural with the tungstates can be synthesized contributes to a better understanding of the phenomenon.

Synthesis of mixed oxide compounds at high pressure and temperature helps establish criteria by which crystal structures may be predicted. At the same time the establishment of such criteria should be helpful in the synthesis of new and useful materials - materials which may have profoundly different properties from those now known.

SCIENTIFIC JIGSAW PUZZLES

ROWENA SWANSON
Information
Research
Division
AFOSR

The familiar jigsaw puzzle embodies pattern-recognition problems. One identifies matching pieces through recognition of picture and shape relationships. Problems of photointerpretation and map-matching involve sophisticated applications of the jigsaw-puzzle technique. In experimentation to develop machine capability for recognizing shapes such as object contours, significant features from curve traces, and printed and handwritten characters, it becomes necessary to be able to describe the path of a continuously changing boundary, to associate matching paths, and to relate unknown with known boundary patterns. Such machine performance in effect requires the solution of jigsaw puzzles based on shape alone.

In a study under the sponsorship of the Directorate of Information Sciences, AFOSR, Dr. Herbert Freeman of New York University has been exploring the classification of geometric shapes, formulation of a criterion for quantization, and algorithmic development for curve analysis, synthesis, and manipulation.[1] The goal of Dr. Freeman and his research group has been the definition of an eventual capability for processing geometric information in a digital computer with the same facility as now pertains for numeric data.

The main difficulty in developing a classification scheme for planar contours is the elusiveness of a clear formulation of

the problem. Thus, research was begun on the jigsaw-puzzle problem which is specific, well-defined, and typical of the general pattern classification problem. Digital solution of the problem should lead directly to a better understanding of the manner in which a computer may be used efficiently for the solution of a wide variety of pattern-recognition problems.

A recent report describes one approach to the encoding of arbitrary geometric configurations.[2] The approach uses a grid-intersection method of chain encoding developed by Dr. Freeman.[3] This involves approximating an arbitrary curve by a series of straight-line segments. Each segment is the side or diagonal of a unit square. The shape and size of a curve are specified by a sequence of numbers representing the sequence of line segments placed end to end. By specifying the location of the starting point with respect to absolute coordinate axes, the position of the curve relative to the axes is determined.

From grid-intersection data, a region can be outlined within which the entire original curve must lie. Although it is not possible to precisely reconstruct an arbitrary curve in the region, it is expected to be possible to identify the smoothest curve which satisfies the constraints of the chain. A set of algorithms have been developed for smoothing the chain data.[4]

The method has been tested on puzzles for which a complete set of pieces is given and for which a unique solution exists. The shapes may be straight or irregular, but the pieces match their neighbors between clearly defined points of discontinuity. Relaxation of these constraints will extend the approach to puzzles having extraneous, missing, ambiguous, and inverted (mirror-image) pieces.

In another report, quantization and encoding based on a parallel-plane intersect method is described.[5] The method consists of passing a series of parallel, equally spaced planes through a surface, determining the curves of intersection of the planes and the surface, and finding the curve points for these planar surfaces. The parallel planes are considered to be planes parallel to the x-y plane comprising a three-dimensional rectangular grid. A curve point is selected in the first plane from which a chain connecting the curve points in that plane is generated. Tracing proceeds from the termi-

nus of the first chain to the closest curve point in the second plane. This procedure is continued until the chain for the curve points in the last plane has been generated.

The chain-encoding technique has been extended to 3-dimensional jigsaw puzzles -- to the analysis of arbitrary 3-dimensional curves and surfaces. A 27-point coding system is being used. Algorithms have been derived to determine whether a chain is planar, the length of a chain, maximum excursions of a chain, its residue, symmetry of chains about planes and axes, points of intersection between chains, and the volume and first- and second-order moments about specified planes of surfaces. Some of the algorithms have been programmed for the IBM 1620. Further study on techniques for synthesizing 3-dimensional object contours from a set of projections of the object is planned. Quantization and encoding may be extended to four- and higher-dimensional puzzles.

A semiautomatic chain encoding device (SACE) was developed for the rapid encoding of geometric curves. As a stylus is manually guided over a contour, electric signals are generated which represent the instantaneous stylus position in a biangular coordinate system. The analog signals are converted to 11-bit binary codes which are received by a Packed Bell 250 computer. A program was written for transferring the chain data from the PB 250 to the IBM 1620.

References:

1. This research has proceeded under grants AF-AFOSR-62-152 and 24-63.

2. Ferdinand Freda. "A Mechanism for Encoding Arbitrary Geometric Configuration." July 62. NYU Technical Note 400-15.

3. Herbert Freeman. "On the Encoding of Arbitrary Geometric Configurations." IRE Transactions on Electronic Computers, vol. EC-10, no. 2, 260-8 (June 61).

4. Herbert Freeman. "On the Digital Computer Classification of Geometric Line Patterns." Proc. National Electronics Conference, Chicago, Ill., 8-10 Oct 62, vol. 18, 312-24.

5. Kenneth Ruttenberg. "Digital Computer Analysis of Arbitrary Three-Dimensional Geometric Configurations." Oct 62. NYU Technical Rept. 400-69.

ATOMIC transition probabilities

THOMAS M. BIENIEWSKI
General Physics Research Laboratory, ARL

When a gas of free atoms is irradiated by a beam of continuous radiation, selective absorption occurs at any wave length capable of exciting the atoms to some higher electronic state. The intensity of the absorption line, thus formed, will depend on the magnitude of the atomic transition probability for that line. The latter quantity is simply the rate at which energy is absorbed from the light beam by the atoms in the gas. For mathematical convenience, this rate is usually characterized in terms of the oscillator strength of the line. By definition, the oscillator strength is the number of classical oscillators whose absorbing action equals that of a single atom in the given line.

To a large extent, past research in spectroscopy has concerned itself with the analysis of atomic spectra and the assignment of term values to atomic levels. By comparison, the study of atomic oscillator strengths has received considerably less attention. Recent applications of measured spectral line intensities, however, have renewed interest in atomic oscillator strengths. Generally, a measurement of the spectral line intensity yields either the line contour as a function of wave length or the total integrated line intensity (also called the equivalent width). See figure one.

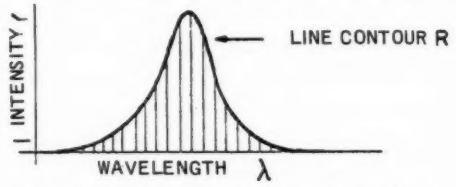


FIGURE ONE: Equivalent width W_λ = Shaded area under line contour

Before any information can be extracted from either quantity, one must know the oscillator strengths for the transition. For this reason, oscillator strengths have important applications in several branches of physics. In astrophysics, they are used to calculate the abundances of various elements in the sun. In plasma physics, oscillator strengths are needed before one can compute the population densities and temperature distribution in a plasma. Also, for the study of any atomic collision process, the oscillator strength is needed to obtain the collision cross section from measurements of the spectral line intensity.

Unfortunately, reliable oscillator strengths are available today for relatively few atomic transitions. Much more research is needed in the field before this lack of adequate oscillator strengths can be remedied. This investigation was, therefore, undertaken to measure the oscillator strengths of the silver resonance lines AG I, $\lambda\lambda$ 3281 and 3383Å and of the cadmium intersystem line Cd I, λ 3261 Å. These measurements were made by the method of total absorption for weak lines.

In this method, a metallic sample is sealed in an evacuated quartz cell and then heated to produce a vapor of the metal in equilibrium with the solid metal. By measuring the temperature of the cell, N, the density of atoms in the vapor phase can be found from published vapor pressure data for the given element. When the cell is irradiated with a beam of continuous radiation, the resulting absorption line is dispersed in a spectrograph and photographed. The photographic plates are developed and then reduced to equivalent widths (see figure one) on a scanning densitometer. For a weak spectral line, the oscillator strength is related to the equivalent width, W λ, by the equation:

$$W_\lambda = \sqrt{\pi}\ \Delta\lambda_D \sum_{n=1}^{\infty} \frac{(-1)^{n-1} C^n}{n! \sqrt{n}} \qquad (1)$$

where $\Delta\lambda_D = \frac{\lambda}{c} \sqrt{\frac{2RT}{M}}$ is the Doppler width of the line in wavelength units. In the expression for $\Delta\lambda_D$, M is the mass of the absorbing atom, T is the temperature of the vapor in the cell, R is the universal gas constant, λ is the wave length of the spectral line, and c is the velocity of light. The dimensionless parameter C is defined by the relation:

$$C = \left[\frac{\sqrt{\pi}\ (2.82 \times 10^{-13})\ \lambda^2}{\Delta\lambda_D} \right] Nfl \qquad (2)$$

where N is the density of atoms in the vapor, l is the length of the absorbing column of vapor, and f is the oscillator strength. The quantity in brackets is simply the absorption cross section per oscillator, while Nfl is the number of equivalent classical oscillators per unit area normal to the direction of l. Once W_λ and N are known, the oscillator strength f can be conveniently evaluated from equations 1 and 2. To within a 10% experimental uncertainty, the results obtained here for silver and cadmium are:

Ag I, λ 3281, f = 0.524
Ag I, λ 3283, f = 0.283
Cd I, λ 3261, f = 1.94×10^{-3}

AIR CONDENSATION *IN HYPERSONIC WIND TUNNELS*

FRED L. DAUM
Hypersonic Research
Laboratory, ARL

To obtain hypersonic flow in a wind tunnel, highly compressed air is allowed to expand through a nozzle to a low pressure. In the expansion process, the potential energy of the high-pressure air is converted to kinetic energy of the high-speed air stream; the amount of expansion determines the stream velocity or Mach number attained. During the expansion process, the air temperature decreases in accordance with the thermodynamic laws governing isentropic flow. It so happens that if the air is at room temperature at the start, the stream pressure and temperature are sufficiently lowered during the expansion so that some of the air begins to condense at the place where the expansion corresponds to about Mach 5. In the condensation process, heat is released and the stream temperature increases; isentropic flow then no longer exists and it becomes impractical to obtain meaningful test results.

A way to avoid the difficulties of this undesirable condensation is to heat the air so that the initial temperature, called the stagnation temperature, is sufficiently high with the result that, throughout the expansion, the air saturation conditions are never reached. However, at the higher Mach numbers the amount of preheat required is so great that this approach becomes impractical. For example, for Mach 12 a stagnation temperature of about 2200°R is required to avoid the saturation conditions; at Mach 15 the required temperature is close to 3200°R.

In the early studies of air condensation in wind tunnels, it had been expected that a degree of air supersaturation would be obtained such as in the case of expanding water vapor in air. If supersaturation would occur, it would have the effect of relieving the high stagnation temperature requirements for avoiding the saturation conditions. However, after a number of investigations in the period 1948 to 1952 at Mach numbers from 5 to 7, it was the general consensus that only negligible amounts of air supersaturation could be obtained in nozzle expansions and little has been reported further on the subject.

The problem of air condensation has recently been studied by ARL in connection with the initial operation of several ARL hypersonic wind tunnels in the Mach number range of 9 to 17. It was found that, at these high Mach numbers, the onset of condensation did not occur until the flow was well into an apparent supersaturated state. (The term "apparent" is used here only because the saturation conditions for air, upon which the measure of supersaturation is based, are not accurately defined in the low pressure and temperature range of interest.) As expected, the effect of supersaturation was to allow the operation of the wind tunnel with condensation-free flow at stagnation temperatures considerably lower than the temperatures dictated by the requirement for avoiding saturation conditions. For example, at Mach 16 it was found that stagnation temperatures of only 1700°R were adequate for avoiding condensation instead of the 3500°R needed to avoid saturated conditions.

Several other interesting results of this study are:

1. At stream static pressures greater than about 3.5 mm Hg, no supersaturation can be expected. (This pressure value is actually based on lower Mach number JPL data.)

2. There appears to be a maximum value of supersaturation being approached as Mach number is increased; this value is about 55°F.

3. One common curve in the pressure-temperature plane was shown to define essentially the onset of condensation for nozzle sizes from 3 to 21 inches in diameter.

4. It was found that the apparent supersaturation increased exceptionally at the lower Mach numbers (less than about 8) in the presence of strong axial velocity, temperature and pressure gradients.

5. The equilibrium saturated expansion theory of Buhler was found to be adequate for predicting the stream static pressure rise due to condensation effects.

6. The stream pitot pressure and the static pressure are indeed both quite sensitive to the effects of air condensation.

The results of this study were presented at the 31st Annual Meeting of the Institute of Aerospace Sciences in January 1963; the reprint of the IAS paper is available as ARL Report No. 63-42.

announcement

The Defense Documentation Center for Scientific and Technical Information (formerly ASTIA) has recently expanded its rapid telephone search service for the official use of organizations authorized such DDC services. This telephone search facility was originally established on 1 January 1963 to retrieve documents on Semiconductor Devices for engineers and scientists desiring to take advantage of DDC's (ASTIA's) vast collection. Because of its success, the telephone service has now been made available for these additional disciplines:

- RADIOBIOLOGY
- MASERS
- BIOLOGICAL WARFARE
- REFRACTORY METALS

Documents which contain significant information about these subject areas have been indexed in depth, using new microthesauri of specific retrieval terms that have been developed for this rapid reference service. UNCLASSIFIED INFORMATION determined to be pertinent to a question will be given by a return telephone call. CLASSIFIED INFORMATION, bibliographies and reports, as desired, will be forwarded to the requestor by the most rapid means available.

To use this telephone search service to retrieve documents from the DDC collection that may be pertinent to your needs, call DDC (JA 5-5800, Arlington, Va.) and use the following telephone extensions which will be manned by specialists in each of the areas:

- SEMICONDUCTOR DEVICES - Ext. 2479
- RADIOBIOLOGY - Ext. 394
- MASERS - Ext. 441
- BIOLOGICAL WARFARE - Ext. 2828
- REFRACTORY METALS - Ext. 2426

NOTICE TO OUR READERS

Requests for further information should be directed to the individual or laboratory of origin.

Addresses are as follows:

AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
Attn: CRI
Laurence G. Hanscom Field, Bedford, Massachusetts

AEROSPACE RESEARCH LABORATORIES
Attn: ARB
Wright-Patterson Air Force Base, Ohio

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH
Attn: SRIL
Tempo D Building
4th and Independence Avenue, S.W., Washington 25, D. C.

OFFICE OF RESEARCH ANALYSES
Attn: RRR
Holloman AF Base, New Mexico

Detailed documentary reports may be obtained from:

OFFICE OF TECHNICAL SERVICES
U.S. Department of Commerce, Washington 25, D. C.

DEFENSE DOCUMENTATION CENTER FOR SCIENTIFIC AND TECHNICAL INFORMATION *
Arlington Hall Station, Arlington 12, Virginia

*** Qualified requestors**

* RESEARCH REVIEW is published by the Office of Scientific and Technical Information (RRYC), Office of Aerospace Research, USAF, Washington 25, D. C. The frequency of this publication is determined solely on the basis of the availability of significant material to report. The objective is to make a positive contribution to the exchange of information about Air Force sponsored and conducted basic research activities. Individuals or groups associated with basic research may obtain copies by written request to the above address.

*** NOTE THE CHANGE OF OFFICE OF RESPONSIBILITY.**

GPO 860106